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OSA-1637-62
COPY 1 OF 1

5 October 1962

Dear Chris,

The enclosed note should give you the rectification information which you requested. If you have any questions, please don't hesitate to get in touch with us.

Best,

Milt

mb

Enclosure: Document 448, copies 1 and 2

cc: ELT Document 448, copy 3

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MDR
4 Oct 62

# THE EQUATION OF A STRAIGHT GROUND LINE WHEN IMAGED BY THE TYPE I-A & I-B CAMERAS

Because of Coriolis effects, the platform points to the left of flight line (Northern hemisphere, Great Circle flight is assumed) by an angle $\delta$ where

$$\delta = \tan^{-1}\left[2\frac{V}{g}\omega_e \sin\lambda\right] \qquad (1)$$

and

$V$ = velocity = 3100 ft/sec
$g$ = effective gravity acceleration = 31.4 ft/sec$^2$
$\omega_e$ = earth rate = $7.27 \times 10^{-5}$ rad/sec
$\lambda$ = latitude.

Thus,

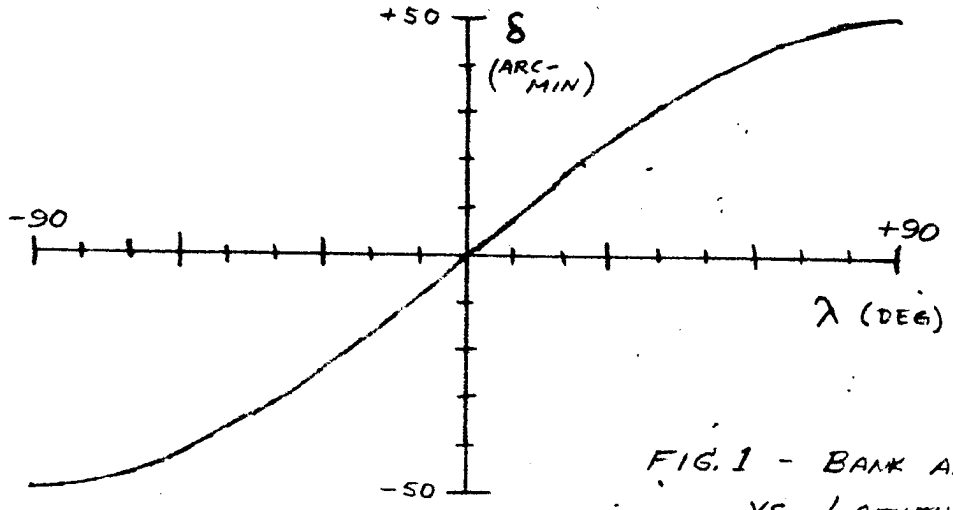


FIG. 1 - BANK ANGLE VS. LATITUDE

In figure 2, the geometry to be considered is shown. Since $\beta=0$ is the angle of the perpendicular to the stabilized camera platform, the Principal point P of the photograph is to the left of the flight line and behind the Nadir. The principal point of the photograph is that point midway between the timing dots which indicate $\beta=0$ (specifically, the last timing dots before the short interruption). Since the Principal point is easily found on the photograph, the line through P and perpendicular to the flight line track will be the line for which an equation will be derived; this is line PN'O in figure 2. Figure 3 relates P, O, and N.

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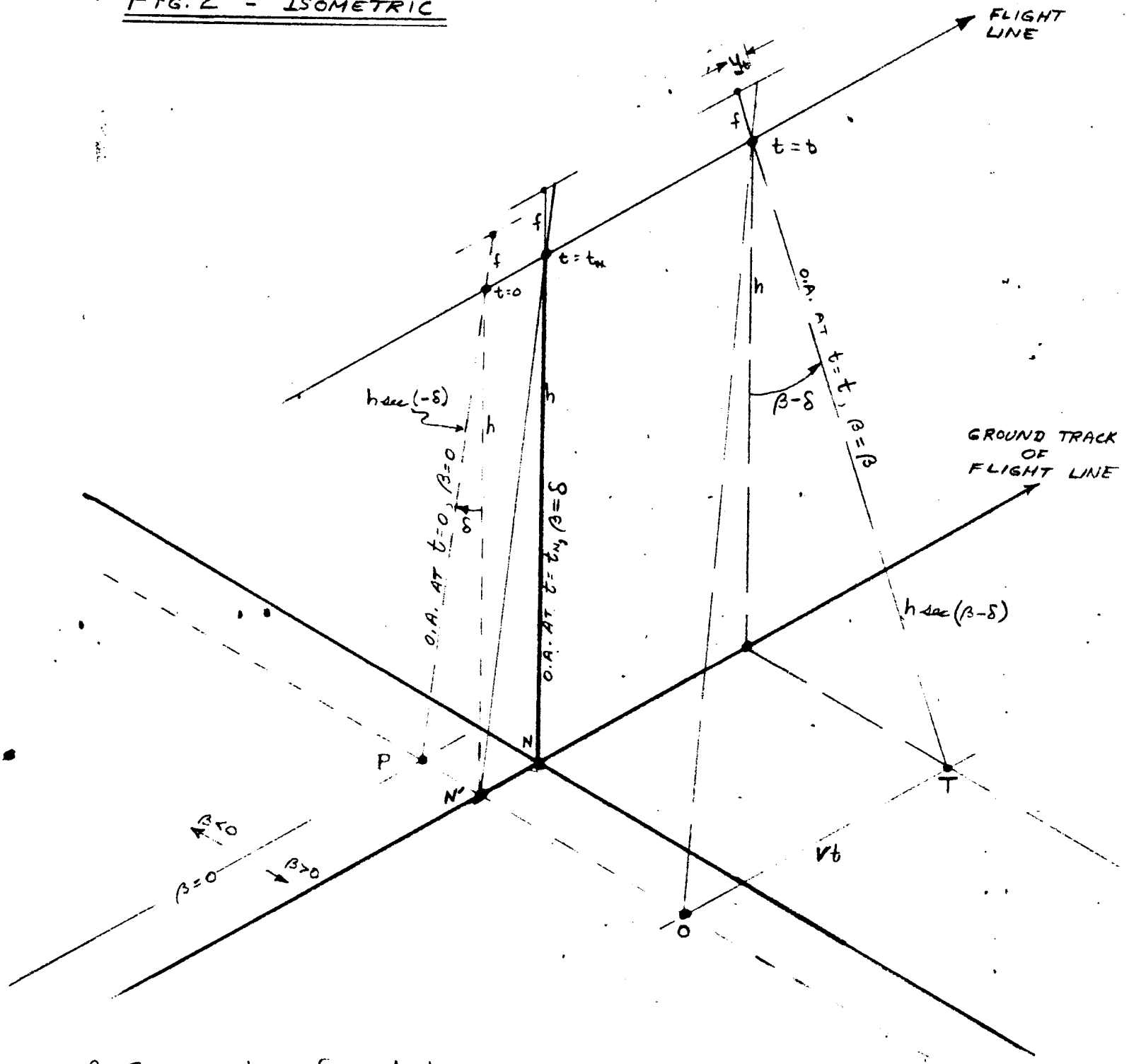
## FIG. 2 - ISOMETRIC




β = Scan angle refered to dynamic vertical
δ = Angle of dynamic vertical to left of perpendicular (Northern hemisphere, Great Circle Flight)
h = Altitude above flat earth
f = Effective focal length
V = Velocity
t = Time
P = Principal point (optical axis intersection with ground at β=0, t=0)
N = Nadir point (point where optical axis is perpendicular to earth)
O = Point on ground track which is perpendicular to flight track
$u_i$ = Image plane distance of O to optical axis

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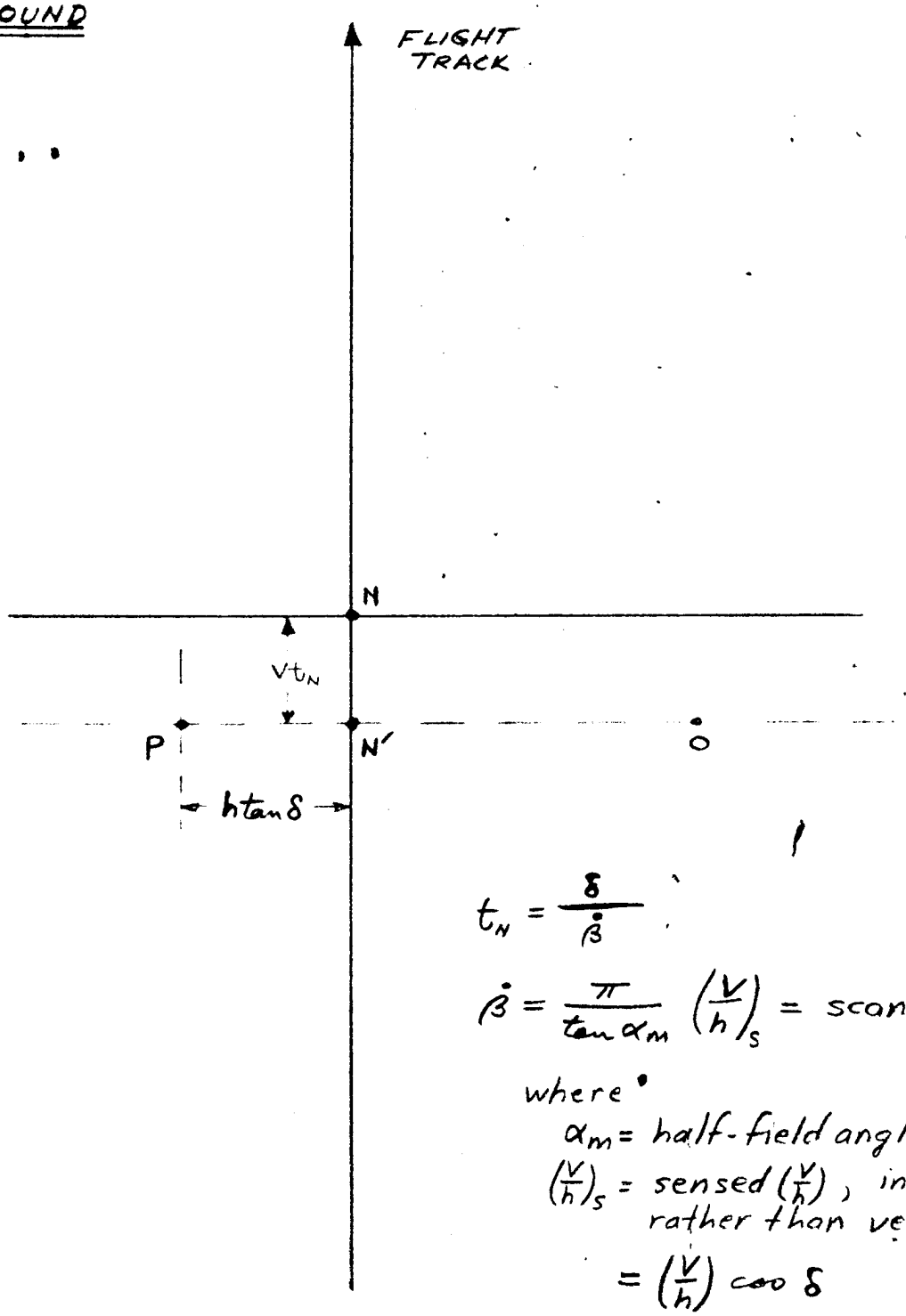
FIG. 3 - TOP VIEW OF GROUND




$$t_N = \frac{\delta}{\dot{\beta}}$$

$$\dot{\beta} = \frac{\pi}{\tan\alpha_m}\left(\frac{V}{h}\right)_s = \text{scan rate}$$

where

$\alpha_m$ = half-field angle = 10°

$\left(\frac{V}{h}\right)_s$ = sensed $\left(\frac{V}{h}\right)$, in $\beta = 0$ plane rather than vertical plane

$$= \left(\frac{V}{h}\right)\cos\delta$$

Since $|\delta| \leq 50'$, $\cos\delta \cong 1.000$; and

$$t_N = \frac{\delta \tan\alpha_m}{\pi}\left(\frac{h}{V}\right)$$

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At time $t=0$, the optical axis intersects the ground at the Principal point P. At time $t=t_N$, the optical axis intersects the ground at the Nadir N. At some time later, the optical axis intersects the ground at a point T, and the image of the point O on the ground line PN'O falls in the slit a distance $y_t$ forward of the optical axis. As seen in figure 4,

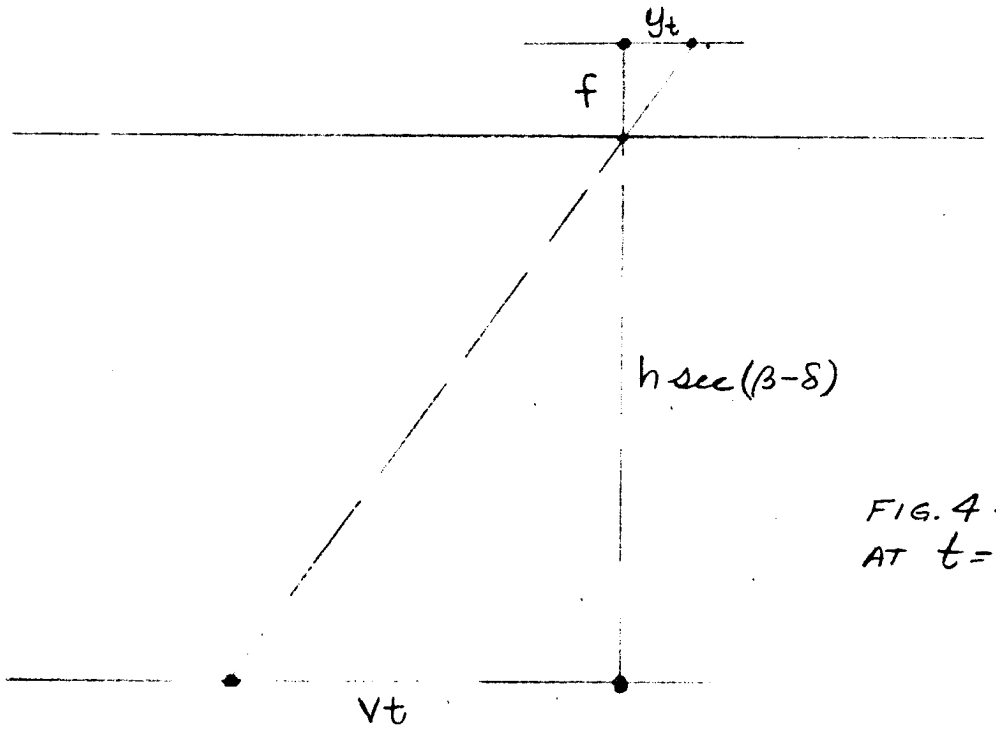


FIG. 4 - SCAN PLANE AT $t=t$, $\beta=\beta$

by use of similar triangles,

$$y_t = f\left(\frac{V}{h}\right) t \cos(\beta-\delta). \qquad (2)$$

Because of camera cycling requirements,

$$\dot{\beta} = \frac{\pi}{t_{an}\alpha_m}\left(\frac{V}{h}\right)_s \qquad (3)$$

and

$$\dot{\beta} = \frac{\beta}{t} \qquad (4)$$

so

$$\Longrightarrow \quad y_t = f\,\frac{t_{an}\alpha_m}{\pi \cos\delta}\,\beta\cos(\beta-\delta). \qquad (5)$$

For $\lambda=0$ (Equator), $\delta=0$, and

$$y_t = 1.01\,\beta\cos\beta \qquad \lambda=\delta=0 \text{ ONLY} \qquad (5A)$$

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If the film did not move in the (fore-aft) y-direction, equation (5) would be the complete solution. However, the film itself is moved by the IMC shuttle with a velocity $\dot{y}^*$ with respect to the optical axis, where

$$\dot{y}^* = f\left(\frac{V}{h}\right)_s \left[\cos\beta + L \sin\lambda \sin\beta\right] - V_f \sin\Psi \qquad (6)$$

in which

$$L \equiv 2\frac{V}{g}\omega_e = 0.0144 \qquad (7)$$

$\Psi$ = skew angle = $2^\circ 40'$

and the film speed $V_f$ is proportional to the scan rate,

$$V_f = f\dot{\beta}\sec\Psi. \qquad (8)$$

Integrating equation (6) with respect to time gives the shuttle position $y^*$,

$$\Longrightarrow \quad y^* = f\left\{\frac{\tan\alpha_m}{\pi\cos\delta}\left[\sin\beta - L\sin\lambda\cos\beta\right] - \beta\tan\Psi\right\} + C \qquad (9)$$

where C is an arbitrary constant of integration (mathematically) and hardware-wise depends on the position to which the shuttle is reset between scans. Numerically,

$$y^* = \begin{cases} 1.01\sin\beta - 0.0146\sin\lambda\cos\beta - 0.839\beta + C & \lambda \neq 0 \\ 1.01\sin\beta - 0.839\beta + C & \delta = \lambda = 0 \end{cases} \qquad (9A)$$

The complete solution for the equation of the image of the line PN'O is

$$\Longrightarrow \quad Y = y_t - y^* \qquad (10)$$

This has been graphed in figure 5 for the case $\lambda = \delta = 0$. For some latitude North of the Equator, the curves will be slightly different, but not very different since $\delta$ never gets very large.

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# FIG. 5 - EQUATION OF LINE PN'O (SOLID CURVE) AND ITS COMPONENTS (DASHED CURVES) FOR $\lambda = 0$

FORWARD IN IMAGE PLANE IN CAMERA

FORWARD ON PROCESSED FILM

+0.6

INCHES ON FILM OR IN IMAGE PLANE

Y

$y_t$ (equn. 5A)

$y^*$ (equn. 9A with $c=0$)

-70

+70

SCAN ANGLE (DEG.)

-0.6

FORWARD CAMERA

AFT CAMERA

NOTE SCALE DISTORTION

0.1 IN

10.0 IN.

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